The Dark Energy Survey: Status and Science Goals

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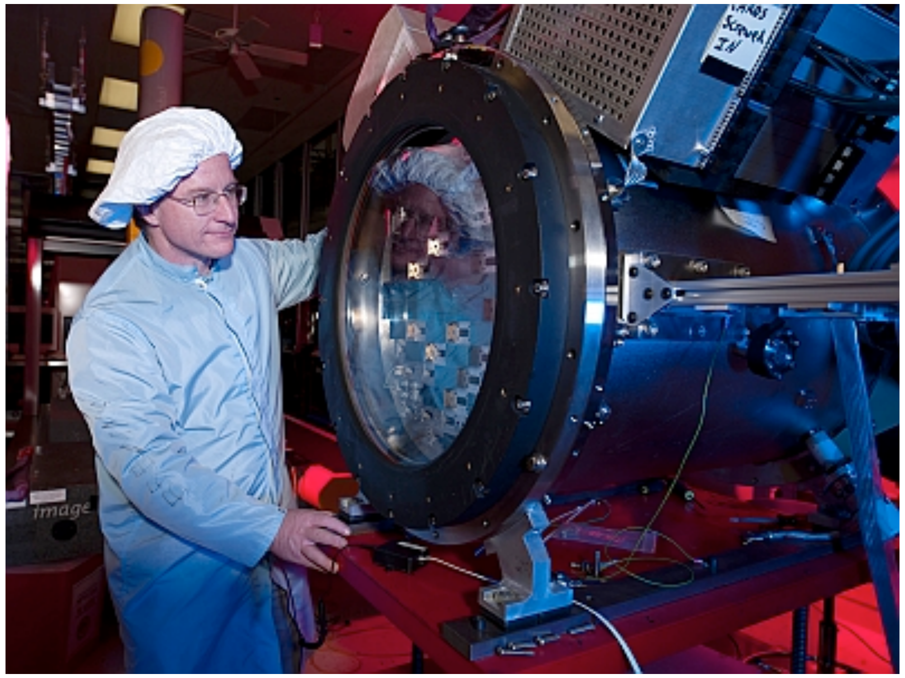
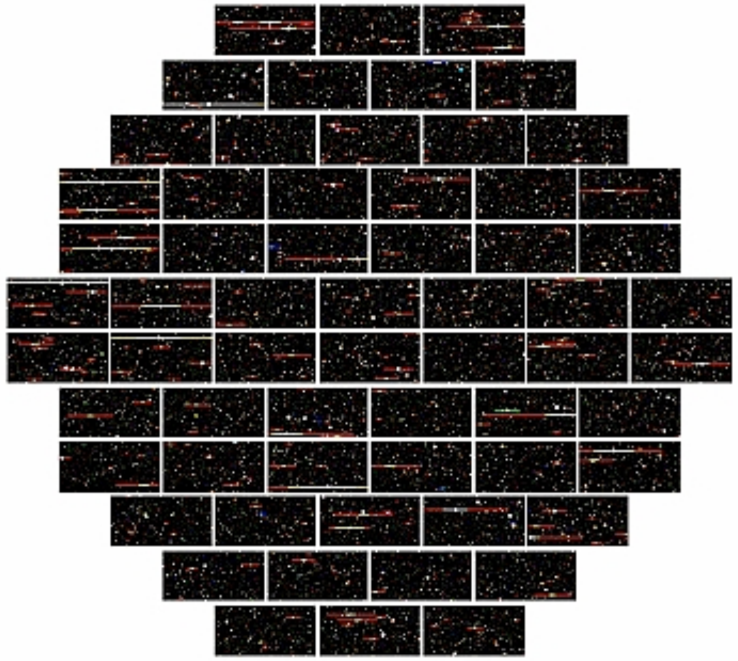
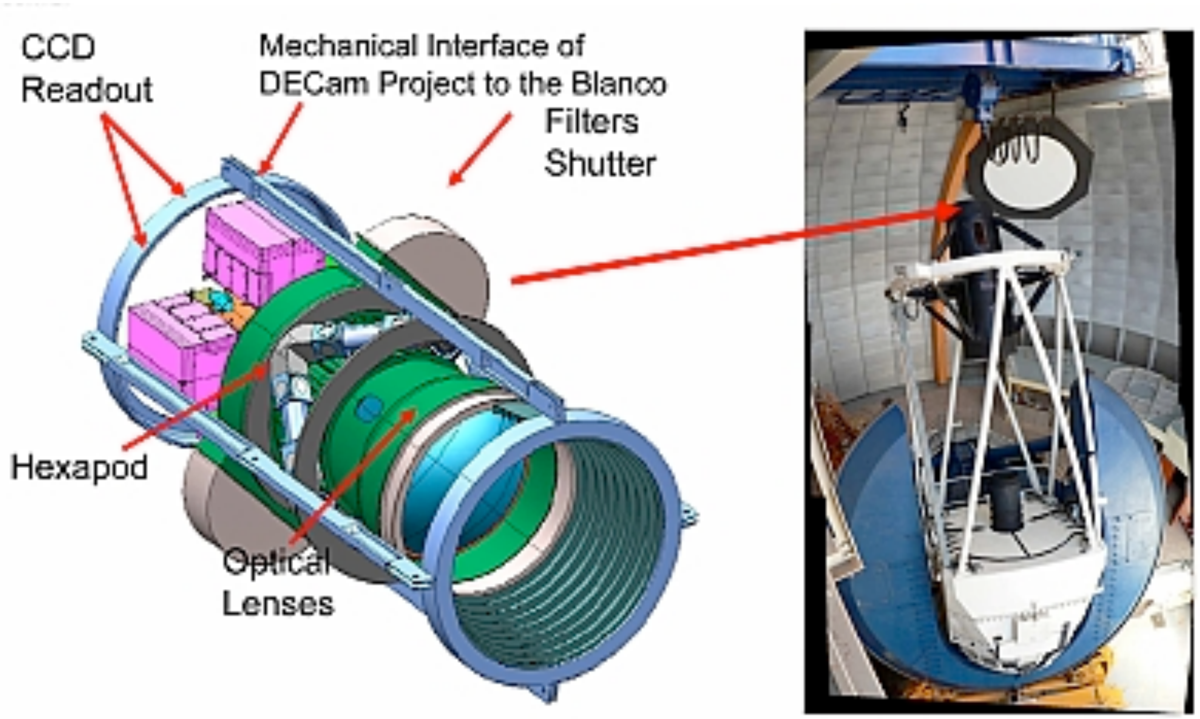
2011-02-17

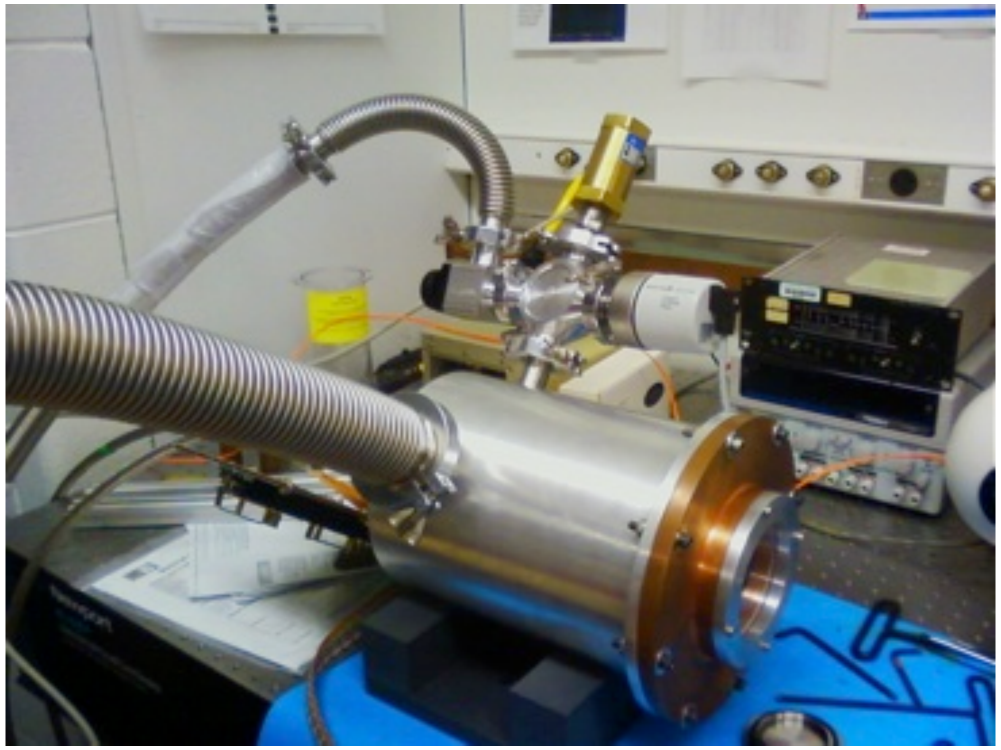
Most Important Results: Detector Capabilities, Hardware Status

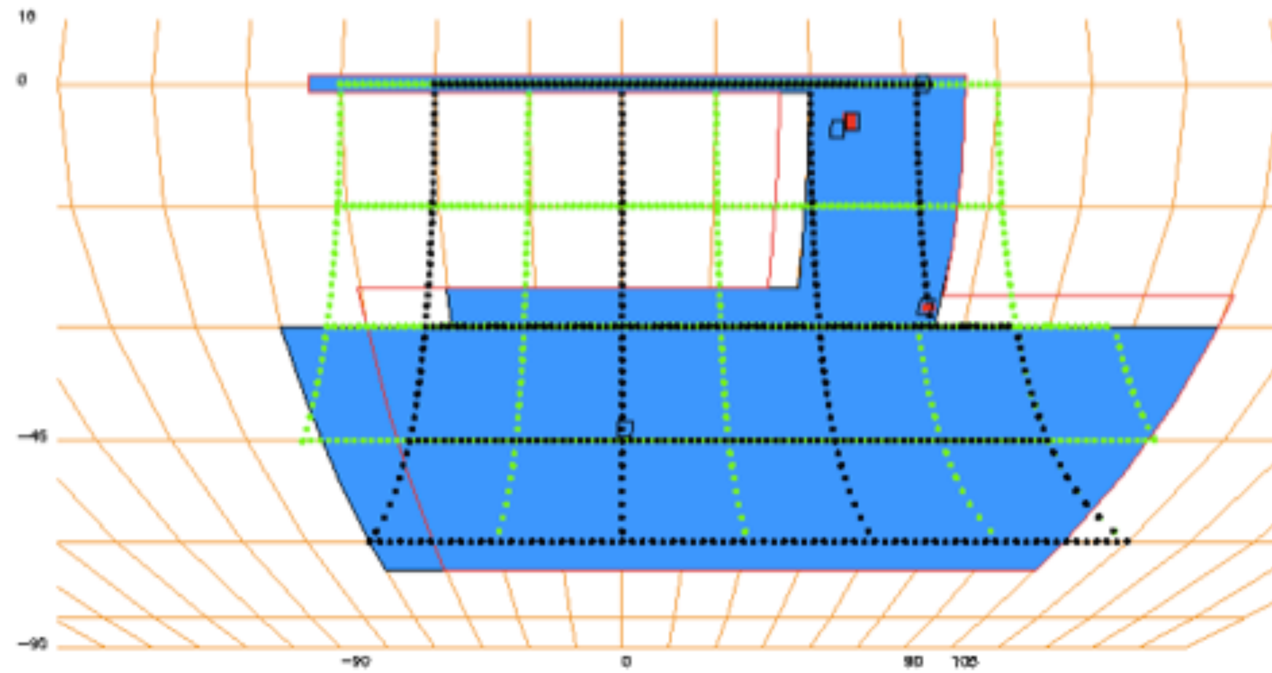


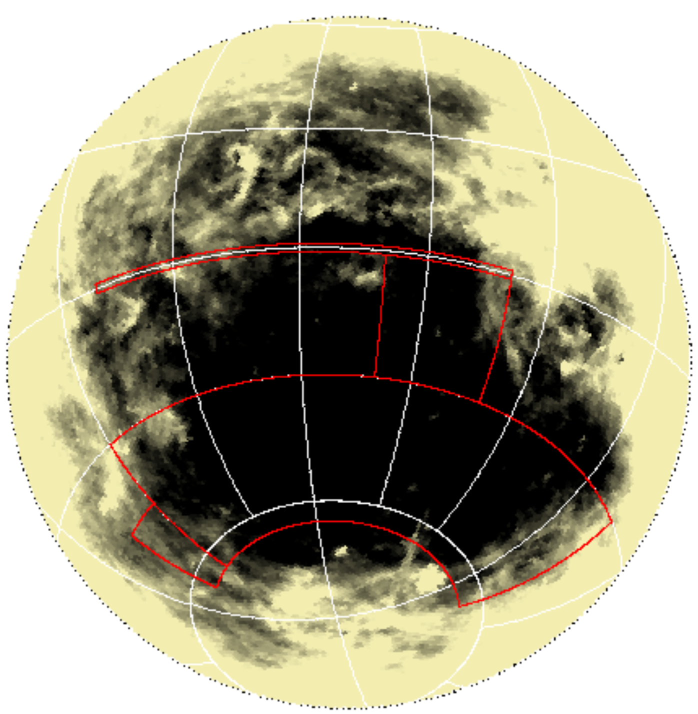


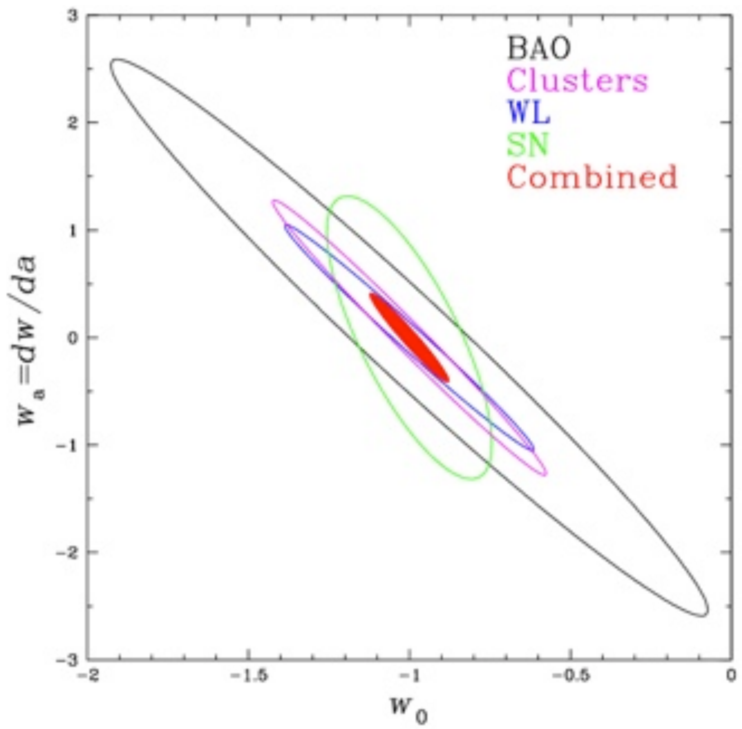


Most Important Results II: Preliminary Science, Survey Goals









The Dark Energy Survey Collaboration

More than 200 scientists and engineers from...

Fermilab — The Fermi National Accelerator Laboratory

UIUC/NCSA — The University of Illinois at Urbana-Champaign

Chicago — The University of Chicago

LBNL — The Lawrence Berkeley National Laboratory

NOAO — The National Optical Astronomy Observatory

United Kingdom DES Collaboration

- UCL - University College London
- Cambridge - University of Cambridge
- Edinburgh - University of Edinburgh
- Portsmouth - University of Portsmouth
- Sussex - University of Sussex
- Nottingham - University of Nottingham

Spain DES Collaboration

- IEEC/CSIC - Instituto de Ciencias del Espacio,
- IFAE - Institut de Fisica d'Altes Energies
- CIEMAT - Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas

Michigan — The University of Michigan

DES-Brazil Consortium

- ON - Observatorio Nacional
- CBPF - Centro Brasileiro de Pesquisas Fisicas

UFRGS - Universidade Federal do Rio Grande do Sul

Pennsylvania — The University of Pennsylvania

ANL — Argonne National Laboratory

OSU — The Ohio State University

TAMU — Texas A&M University

Santa Cruz-SLAC-Stanford DES Consortium

- Santa Cruz - University of California Santa Cruz
- SLAC - SLAC National Accelerator Laboratory
- Stanford - Stanford University

Munich—Universitäts-Sternwarte München

- Ludwig-Maximilians Universität
- Excellence Cluster Universe

The Era of Observational Cosmology

Two (competing!) observations of supernovae showed that the cosmos is dominated by a mysterious “Dark Energy” that drives the accelerated expansion of the universe, and subsequent observations utilizing different probes (e.g. CMB) have confirmed this result.

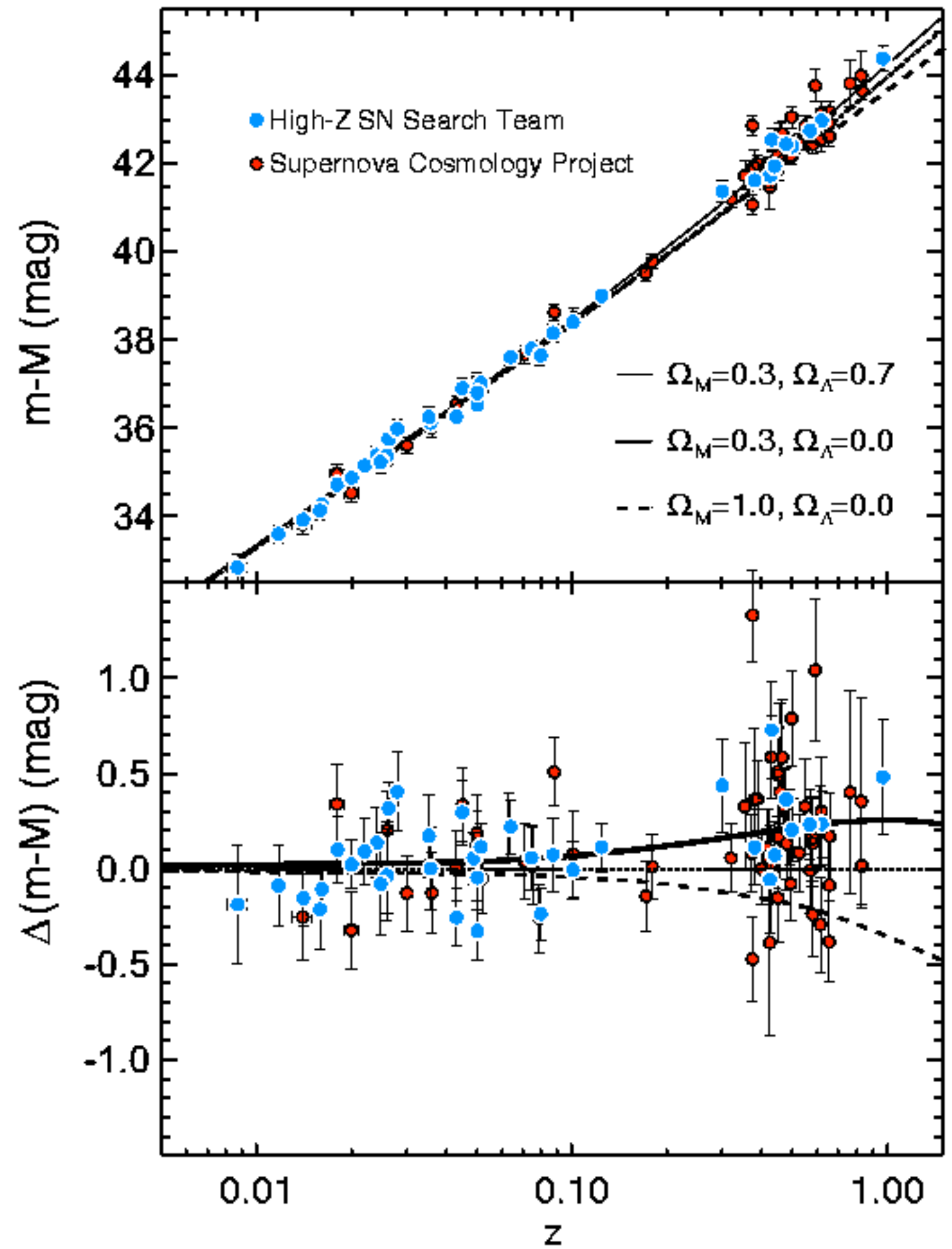
The properties of Dark Energy can be expressed in terms of its Equation of State at different redshifts:

$w(z) = p/\rho$

We parameterize w(z) as follows:

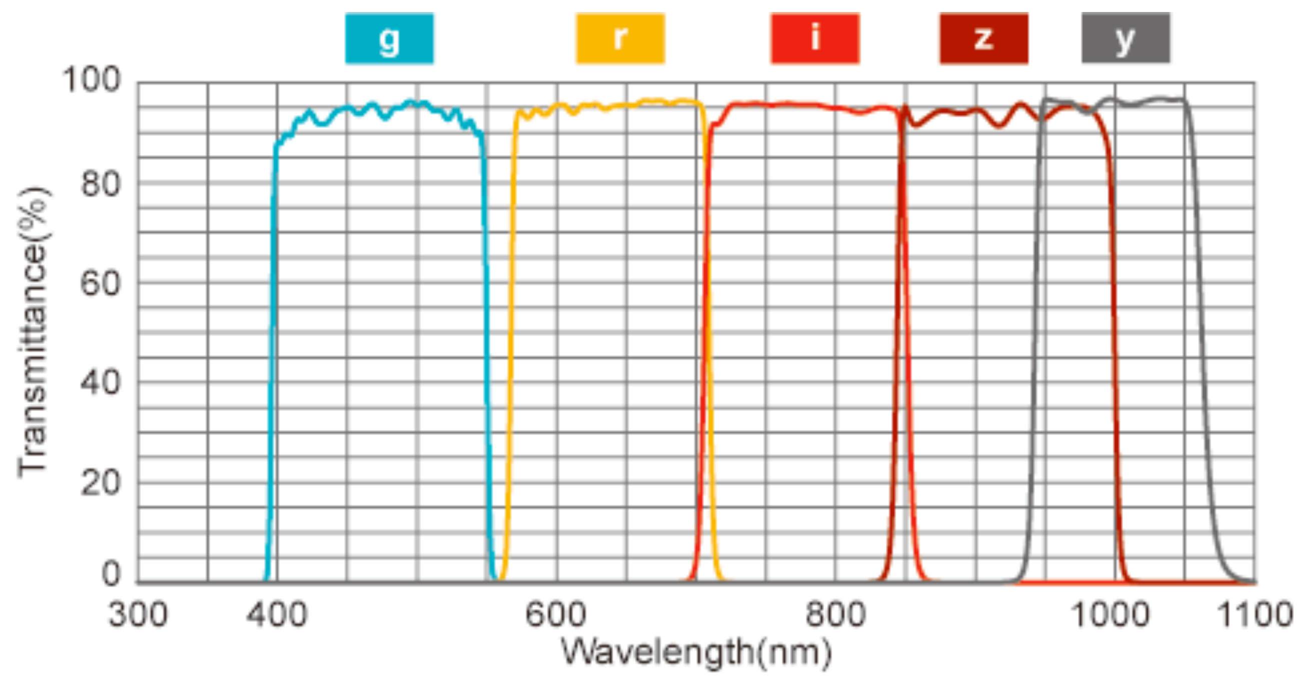
$w(z) = w_0 + w_a(1-a)$, where **$a=(1+z)^{-1}$**

$w_0 = w_\Lambda$ (i.e. the cosmological constant) if $w_a = 0$.



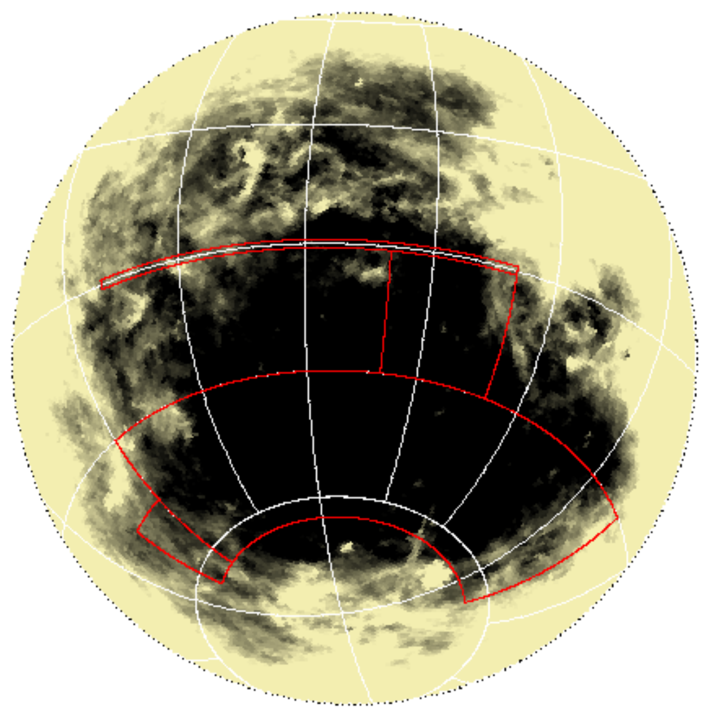
The Dark Energy Survey

Starting in 2012, DES will observe 5000 deg^2 of the southern sky over 525 nights with (SDSS-like) grizY filters. The DES "footprint" overlaps with VISTA Hemisphere Survey (DES Y-band data ⟷ VHS JHK data), as well as SDSS, SPT, and Skymapper.

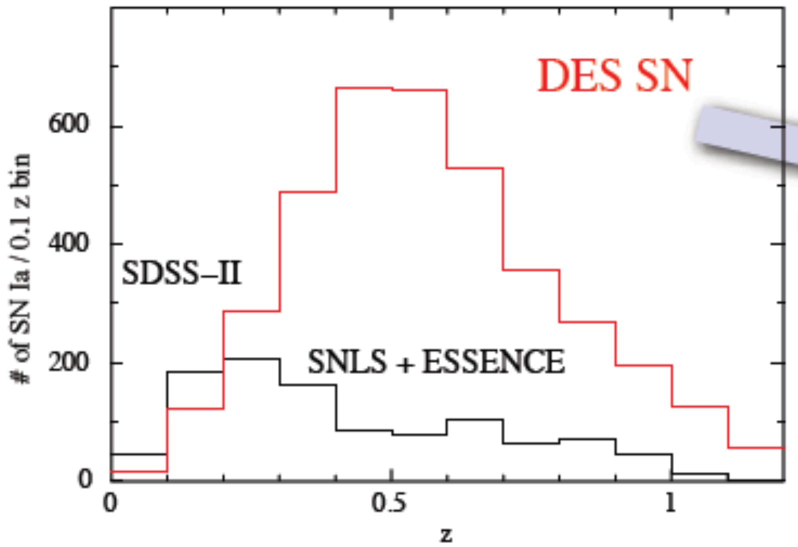


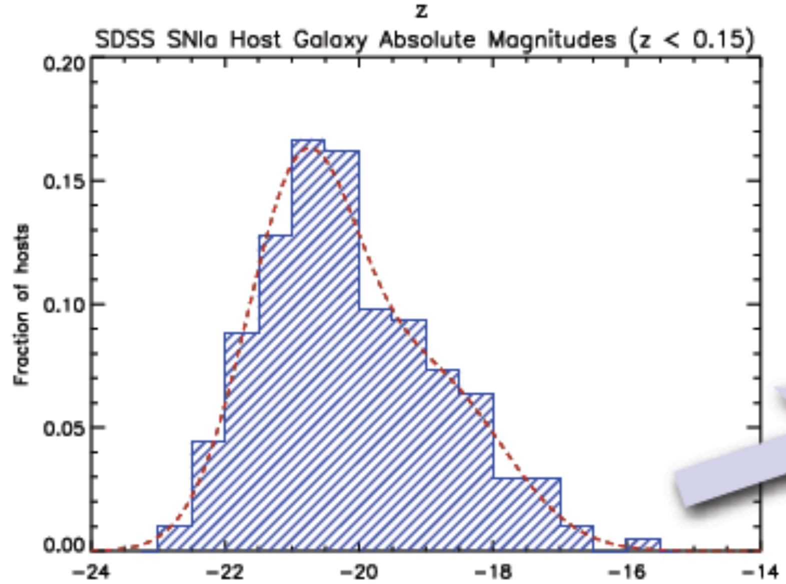
DES uses four complementary methods to constrain the Dark Energy Equation of State:

- Supernovae
- Galaxy Clusters
- Weak Lensing
- Large Scale Structure

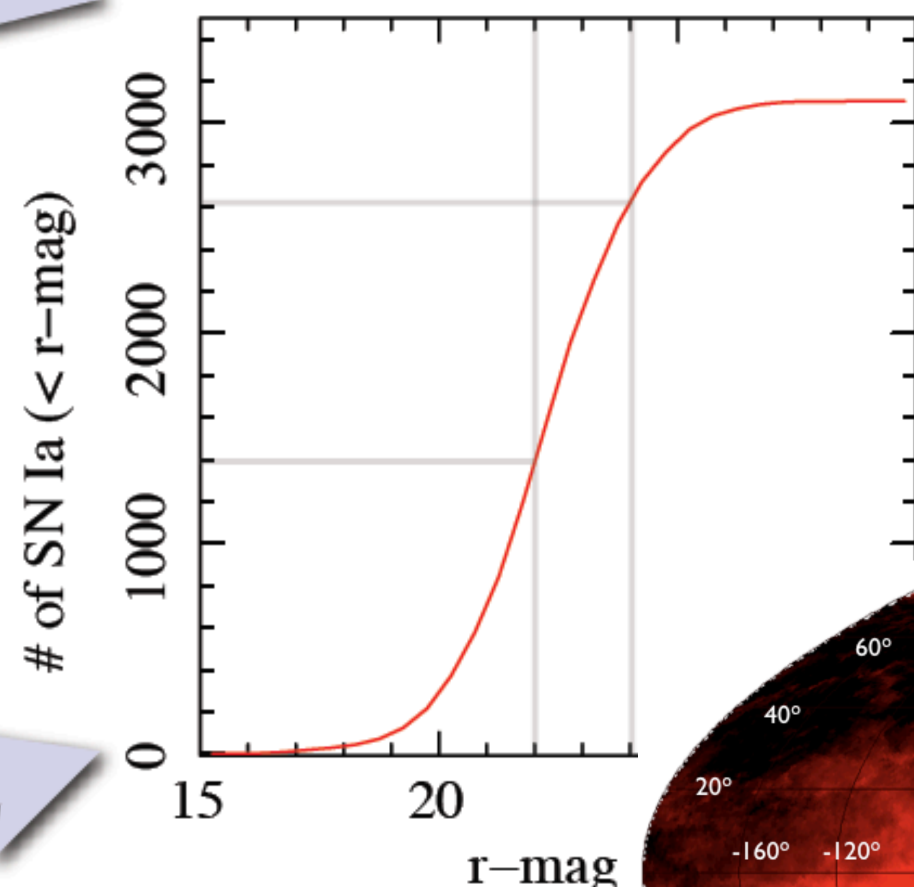


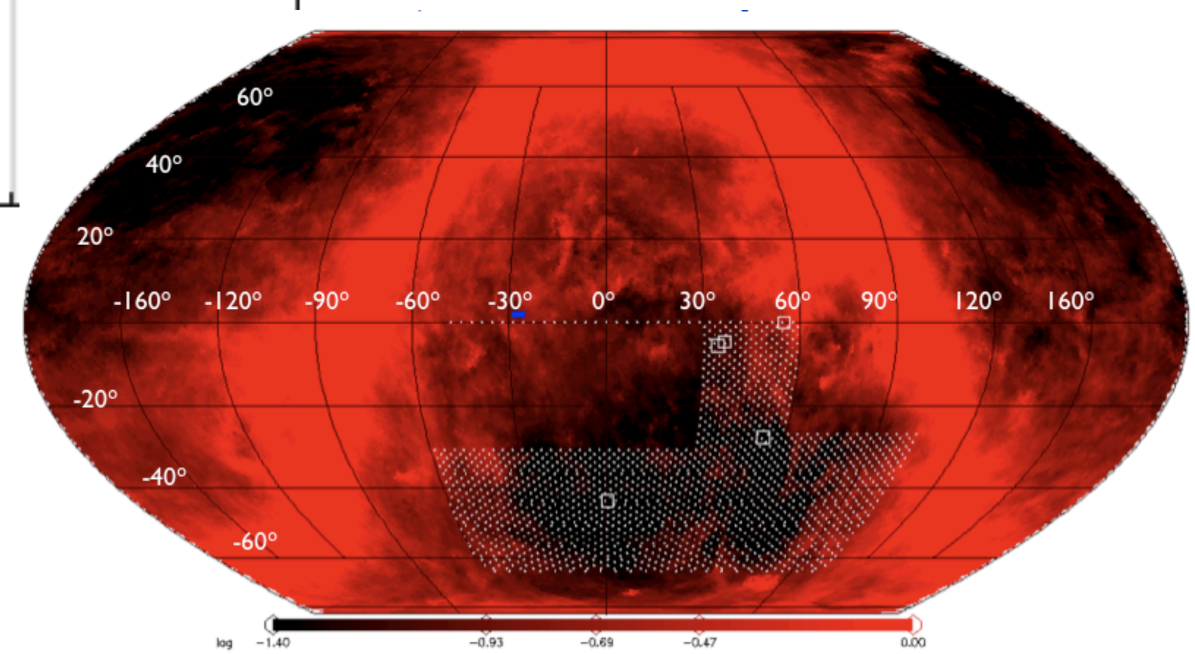
Supernovae



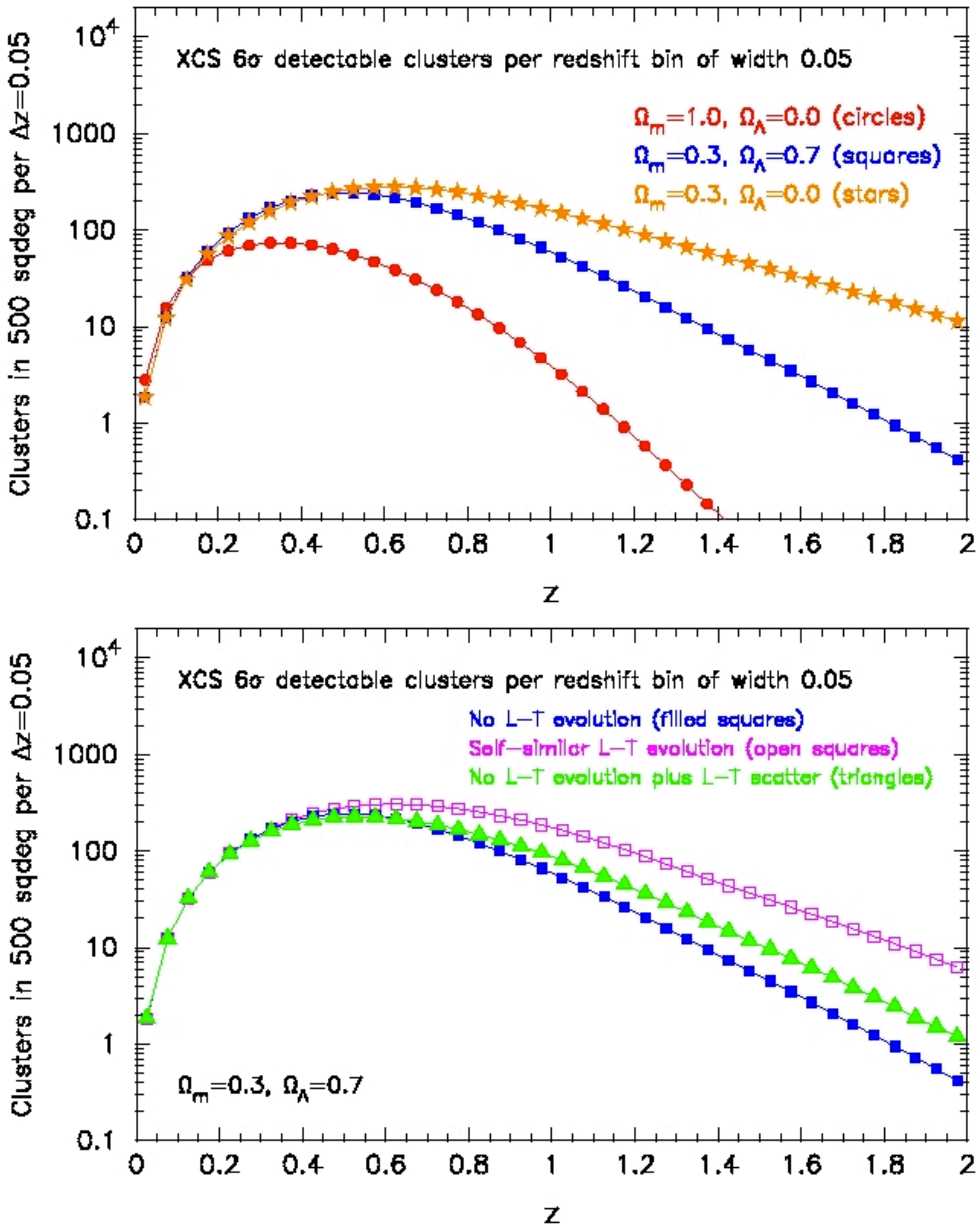


(no evolution &
no K-correction!)



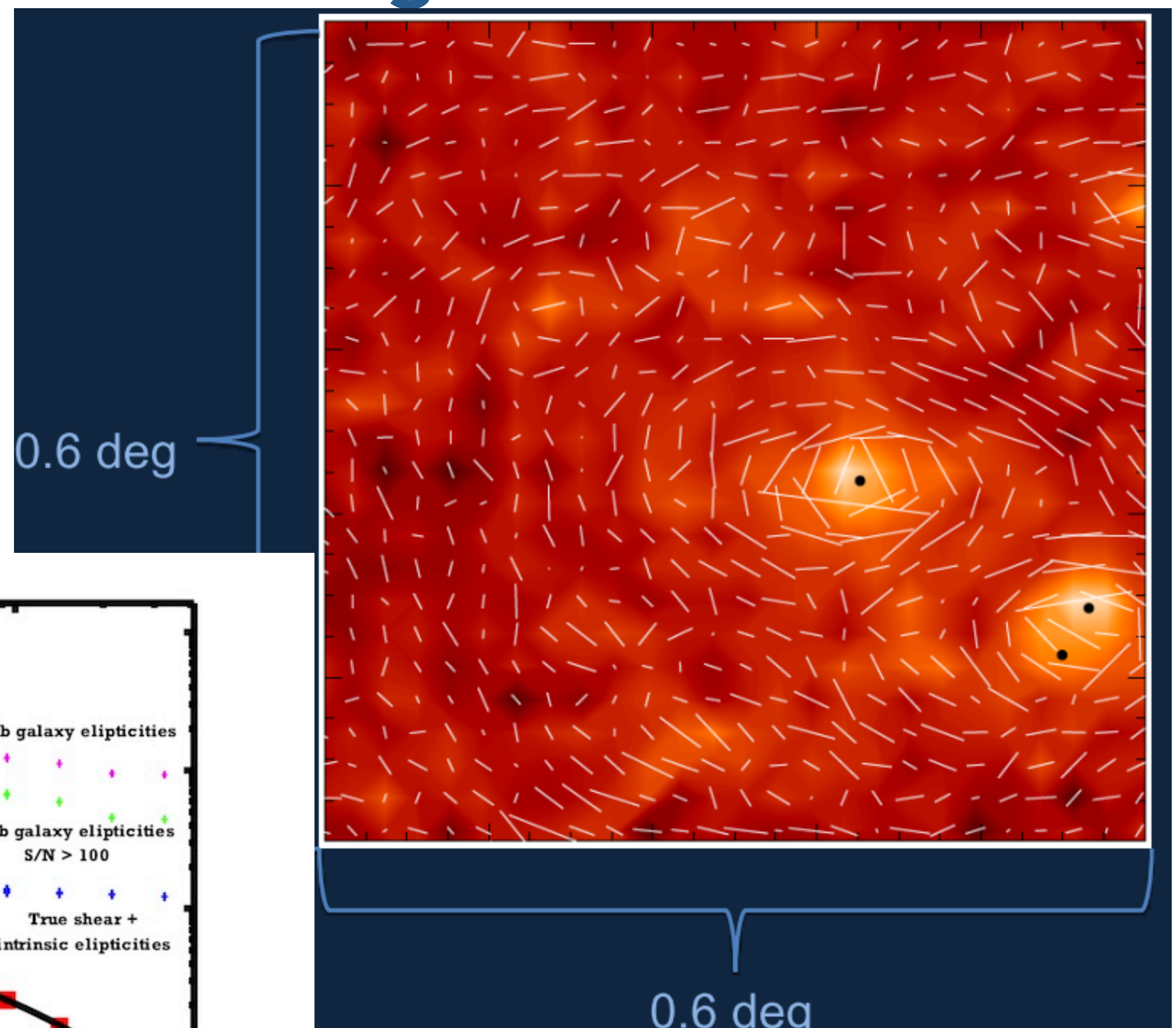


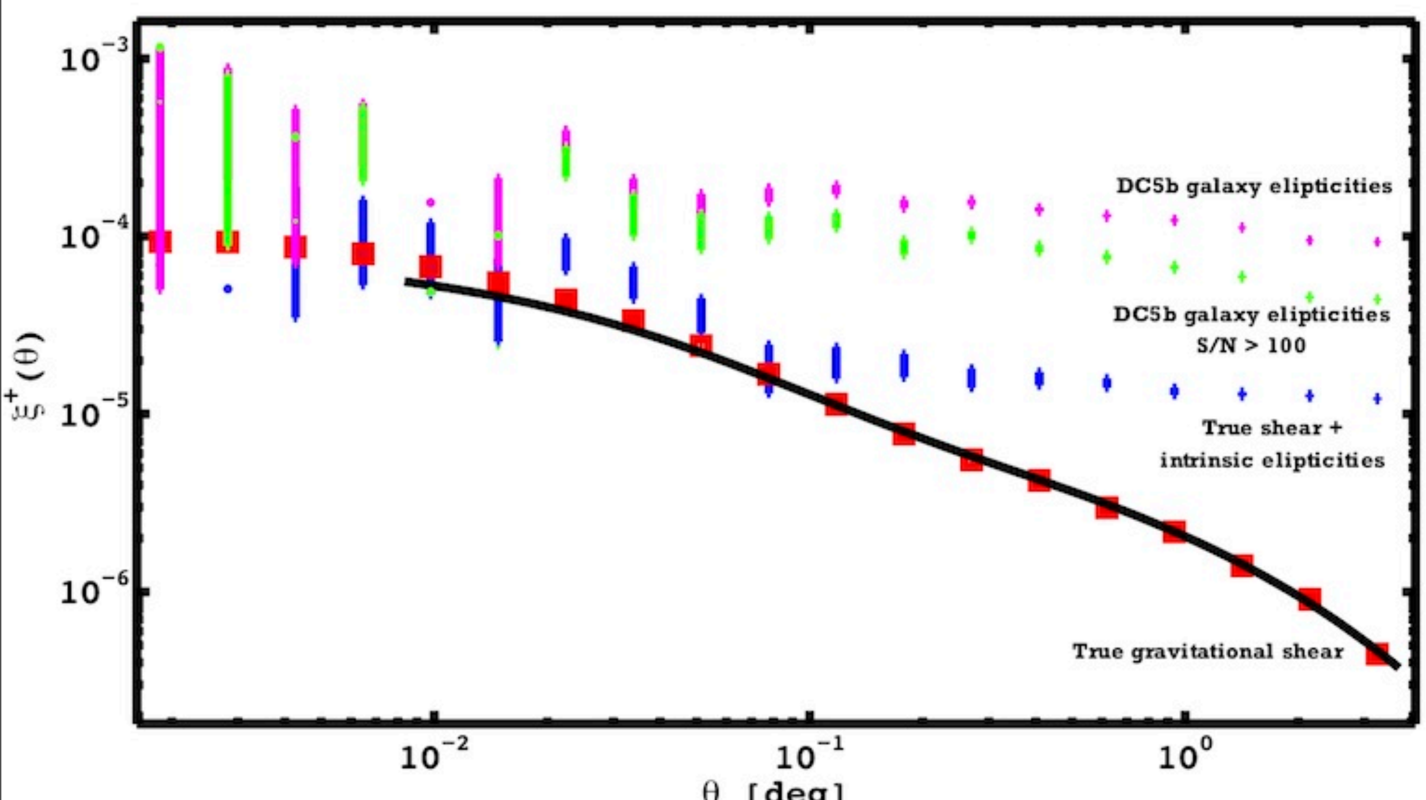
Galaxy Clusters



Weak Lensing

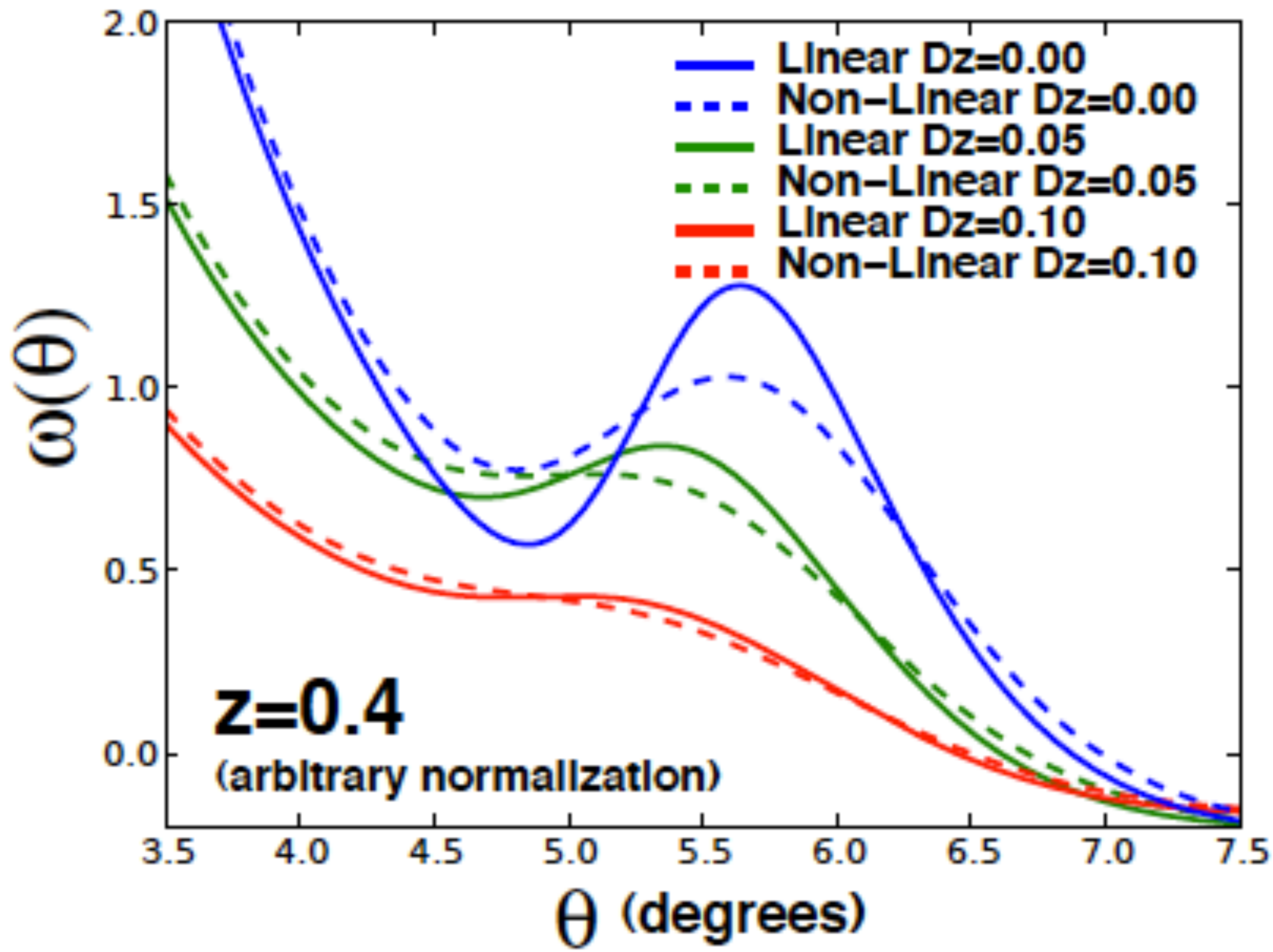
galaxy shear map produces 2-point correlation function, which yields constraints on w_0, w_a





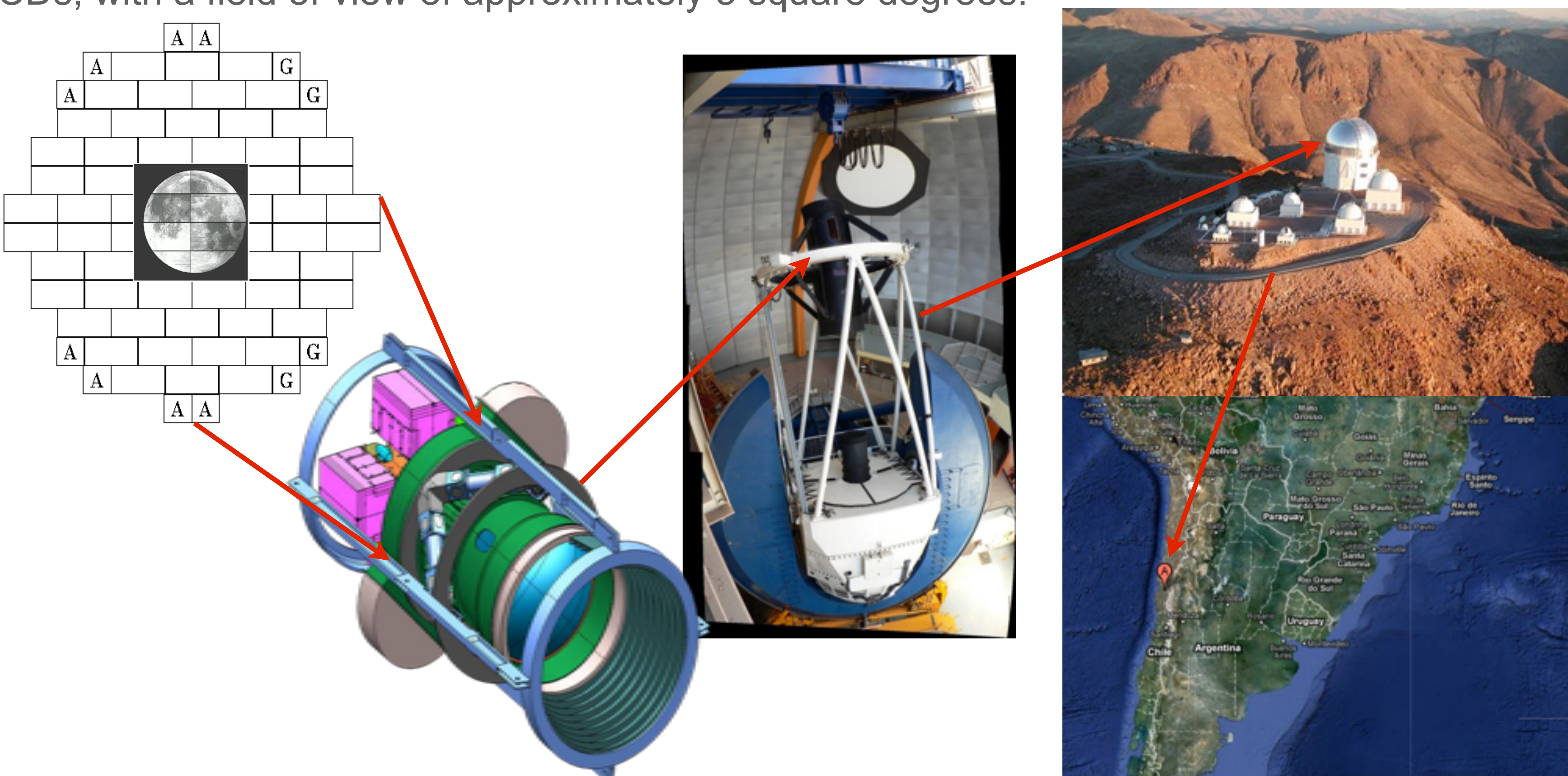
Large Scale Structure

Galaxy-Galaxy (Angular) Correlation

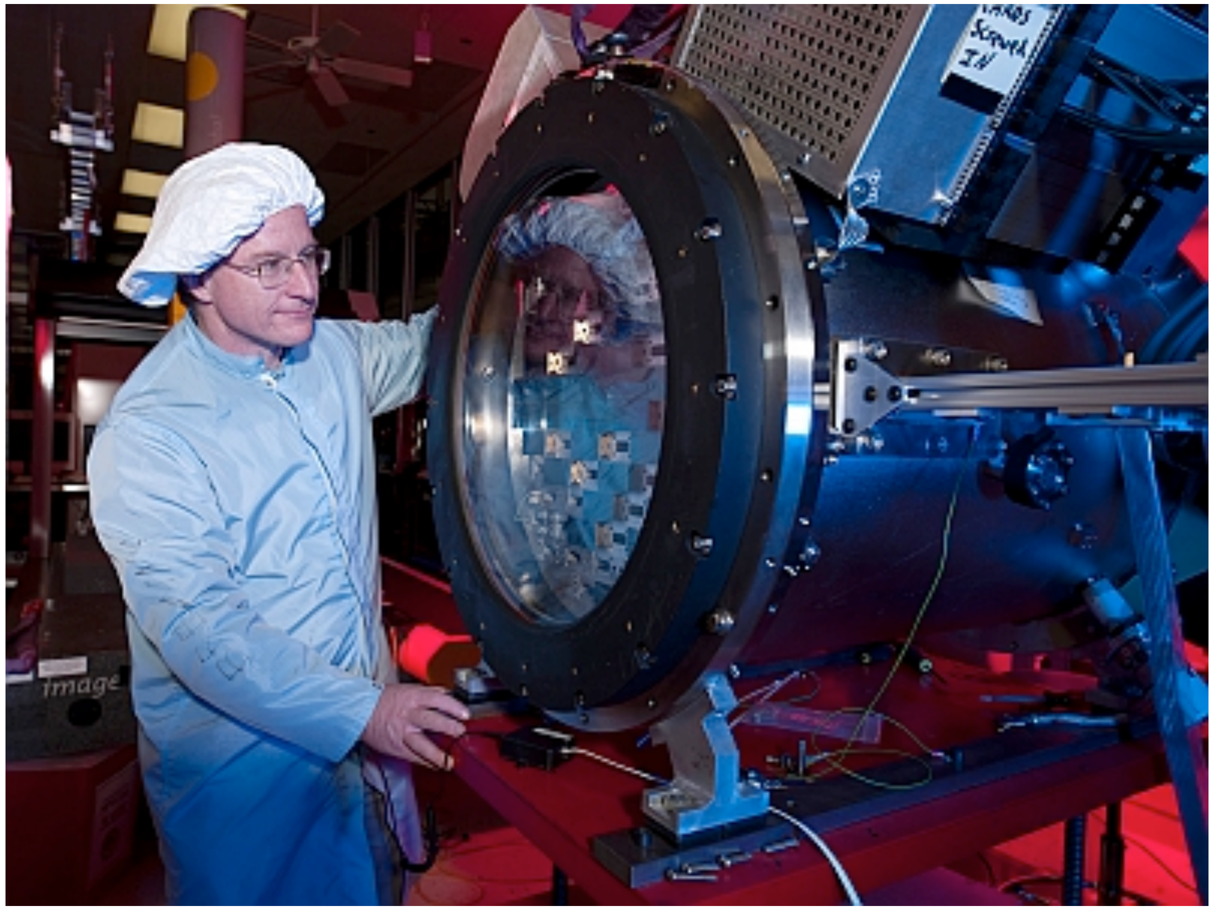


The DES Instrument: DECam

The newly-constructed Dark Energy Camera will be installed at the prime focus of the 4m. Blanco Telescope at Cerro Tololo Inter-American Observatory in Chile. DECam consist of 62 2k x 4k extremely red-sensitive (QE > 50% at 1000nm) CCDs, plus associated guide/focus CCDs, with a field of view of approximately 3 square degrees.



DES/DECam Components



Camera: Science CCDs, Guide/Focus CCDs, Focal Plane, Pressure Vessel

Optics, Filters: 5 lenses >1m. in diameter + grizY filters

Shutter: fast (>0.1 s) control, large enough for ~1m. diameter focal plane.

DAQ Electronics: Vacuum Interface Boards to Monsoon Crates

Cryogenics/Heating: 200L of LN2, vessel controlled to within 0.25K

Pressure Control: ~1m^3 held to P<10^{-4} torr

Hexapod: mm-level positioning of a multi-ton instrument

f/8 Handling System: for other Blanco instruments

Software: Instrument, Infrastructure, and Image Control--SISPI; ObsTac

Simulations: Image-level (pixels) and Catalog-level

DESDM: Data Management of all data products

Science Analysis Tools: SN, WL, Clusters, BAO, "non-key" science

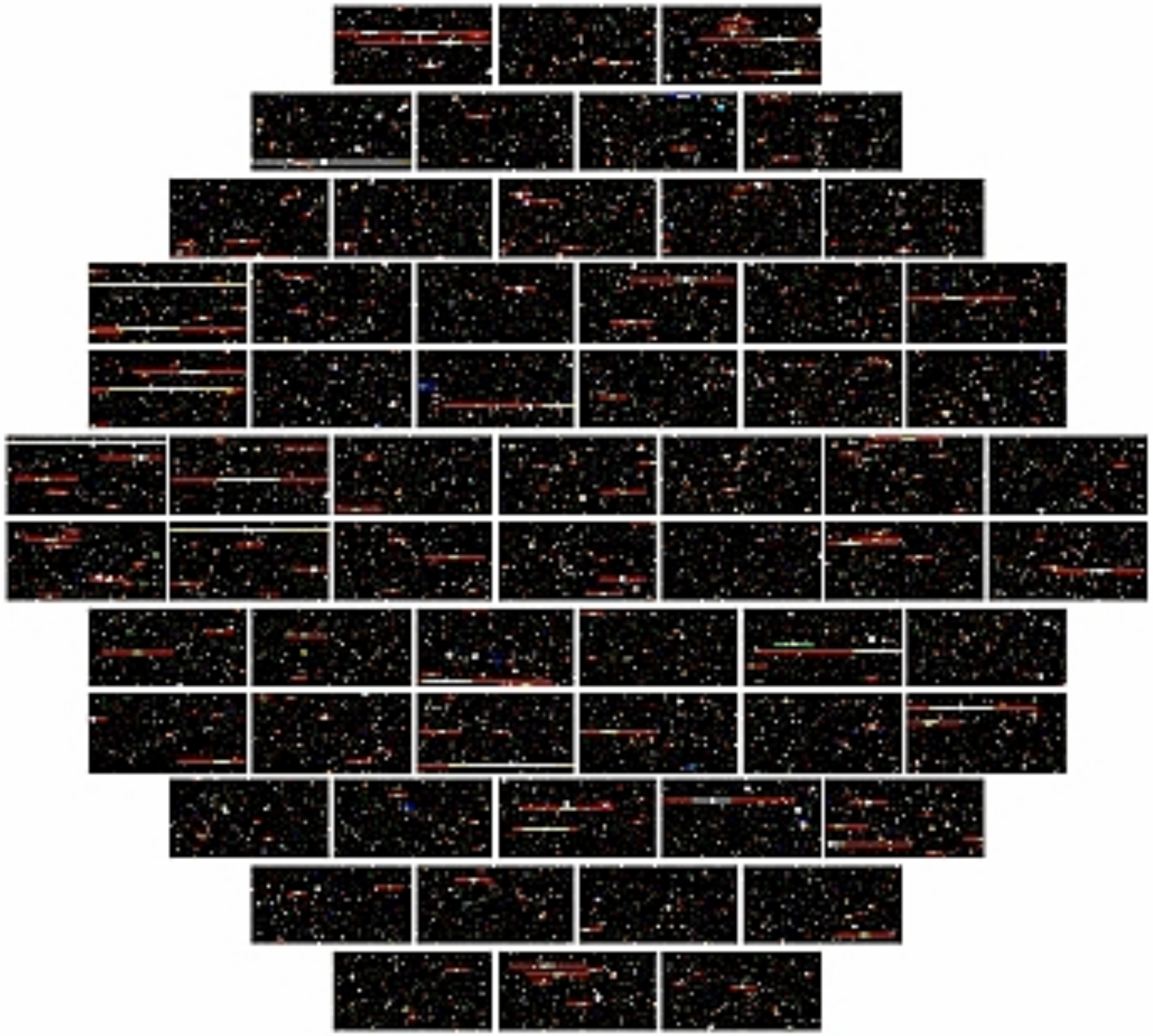
DES Simulations

Simulations must be accurate enough to test processing and analysis pipeline for most stringent requirements (usually set by Weak Lensing). Star-galaxy separation is the biggest challenge.

Currently in DR6 cycle...

Each new (~annual) DR incorporates additional image effects. Includes both large-area simulations (~200 deg^2), as well as smaller (~20 deg^2) “Golden Standard” nights with significantly improved detail.

Each simulation requires ~days of Fermi Grid computing time (Particle-physics like datasets).



DES Image Acquisition/Processing Software

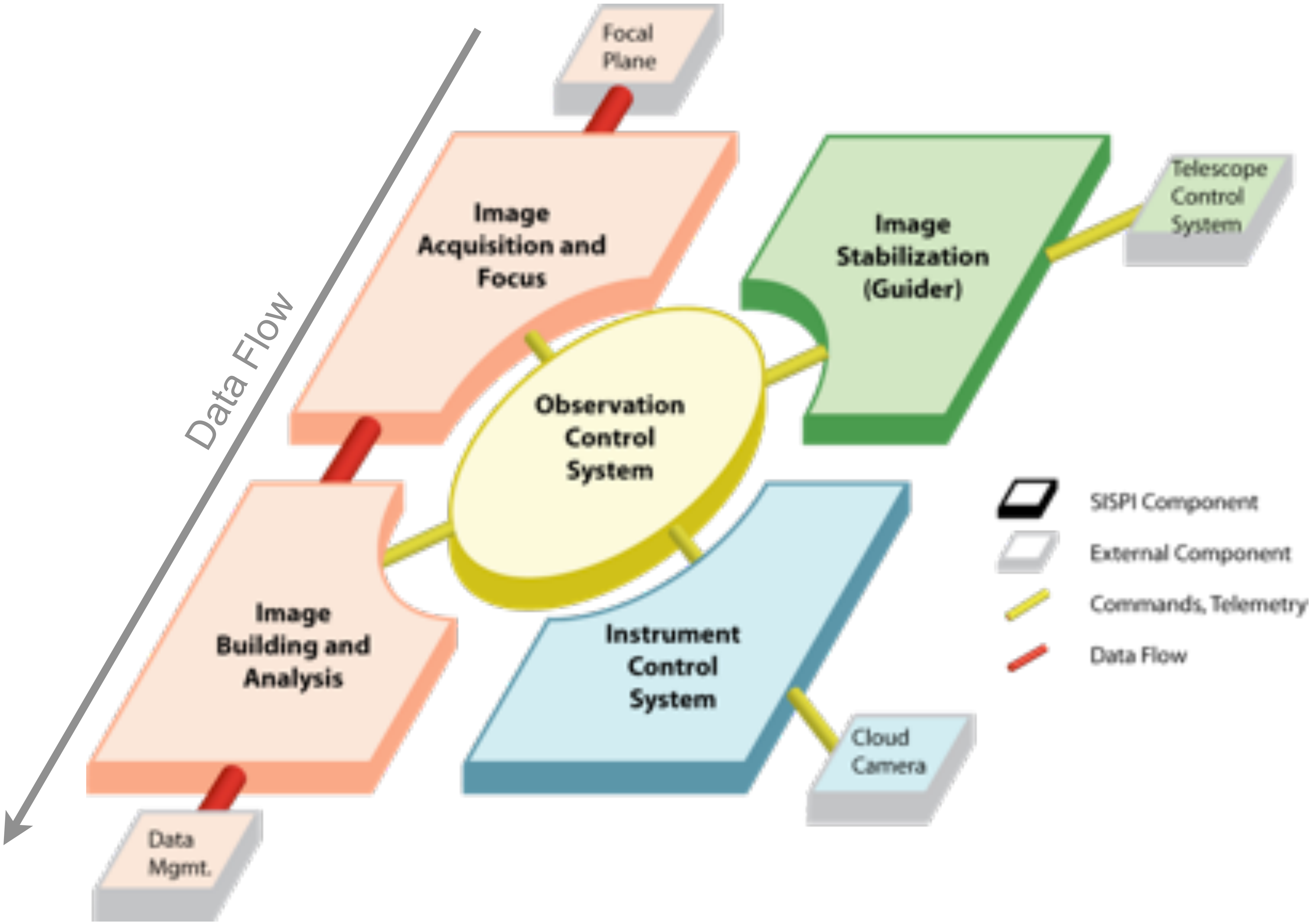
DES will acquire ~1GB images every ~2 minutes for ~8 hours every night. With associated metadata, DES will generate >1PB of data!

These images need to be minimally processed and viewable in (near-) real-time for quality assurance purposes.

A few components include:

- Observation Control System includes GUI interfaces for control
- Instrument Control System includes filter/shutter control
- Focus Control provides feedback during (and between) exposures
- "Image Display" down-samples 1GB image to ~10MB in <2 seconds.
- "Image Health" calculates characteristics of each CCD (background, dead/hot pixels, sample object size and ellipticity) in < 10 seconds.
- DESDM--data transmission, storage, and analysis:
  - "Brazil" Portal for online image processing (dark subtraction, flat-fielding, co-addition, initial science)
  - CTIO 3-Day Storage and Data Transport System for local image cache and transmission to NOAO-Tucson/NCSA/Fermilab, respectively.

Survey Image System Process Integration (SISPI)



Argonne NATIONAL LABORATORY

DES Image Calibration

Requirement:

- Hundreds of Southern Hemisphere standard stars per square degree
- Y-Band standards particularly needed

Purpose:

- Extinction standards and (nightly) photometric solutions
- Facilitate transformation to previous standard systems (e.g. SDSS)
- Requirement of 2% photometry, Goal of 1% photometry

Problems:

- Most current standard stars would saturate DECam
- This could take up to 10% of the survey observing time...

The Solution:

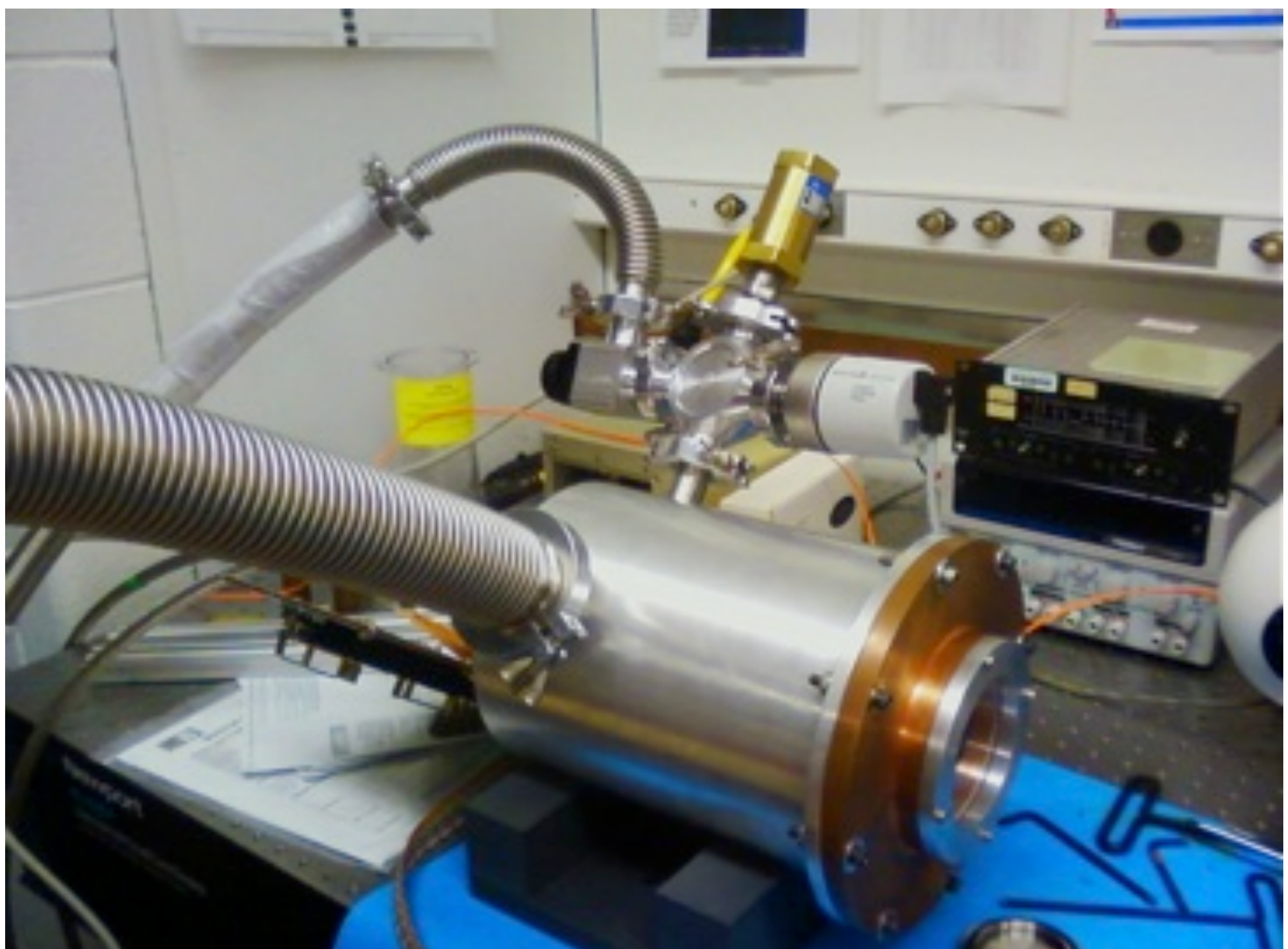
Precursor observations in the DES footprint prior to the start of the Survey, with a smaller (but similar) system...PreCam

U.S. DEPARTMENT OF ENERGY

PreCam

PreCam was constructed at Argonne, and consists of two 2k x 4k CCDs identical to those that will be used in the Dark Energy Survey, along with a pressure control system, cryogenics, and other hardware functionally similar to DES.

PreCam also provides a test of DES-style filters, readout electronics, and software infrastructure for instrument control, telemetry feedback, and survey strategy..

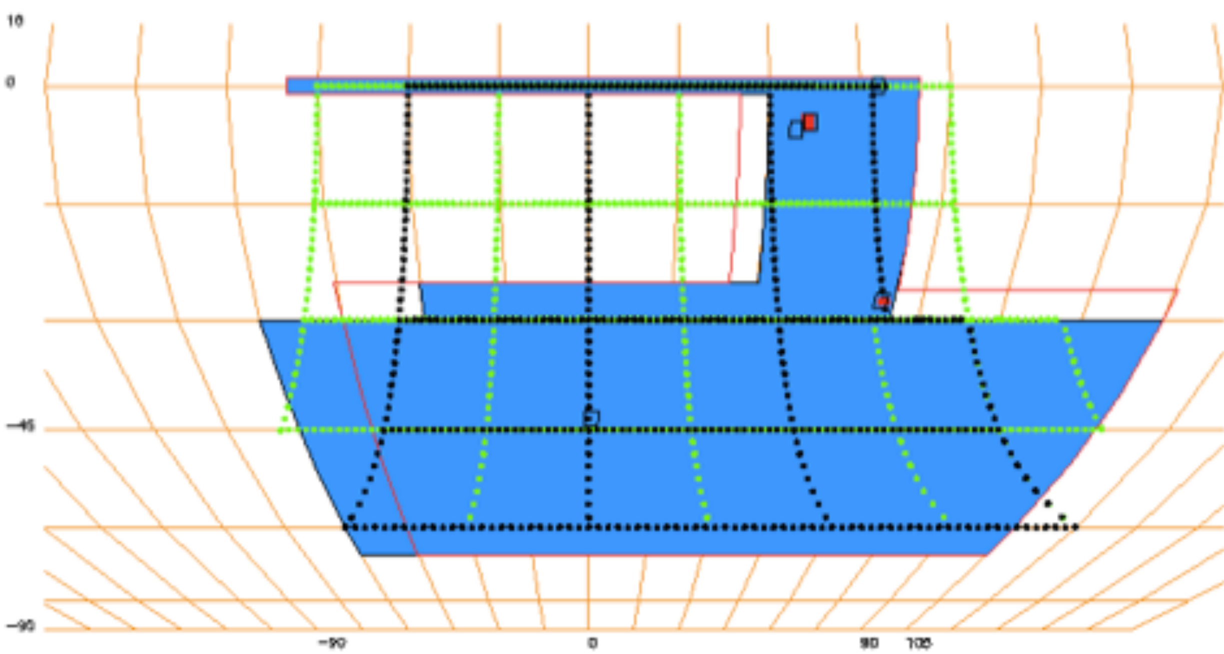


PreCam II

PreCam received 100 nights of observing time in 2010-2011 on the University of Michigan Curtis-Schmidt telescope at CTIO. Approximately 2/3 of that time was scheduled for science observing.

The larger pixel scale afforded by the Curtis-Schmidt allowed PreCam to observe nearly the same FoV as DECam, but to brighter magnitudes more suitable for standard stars.

Possible continuation of observations being discussed...



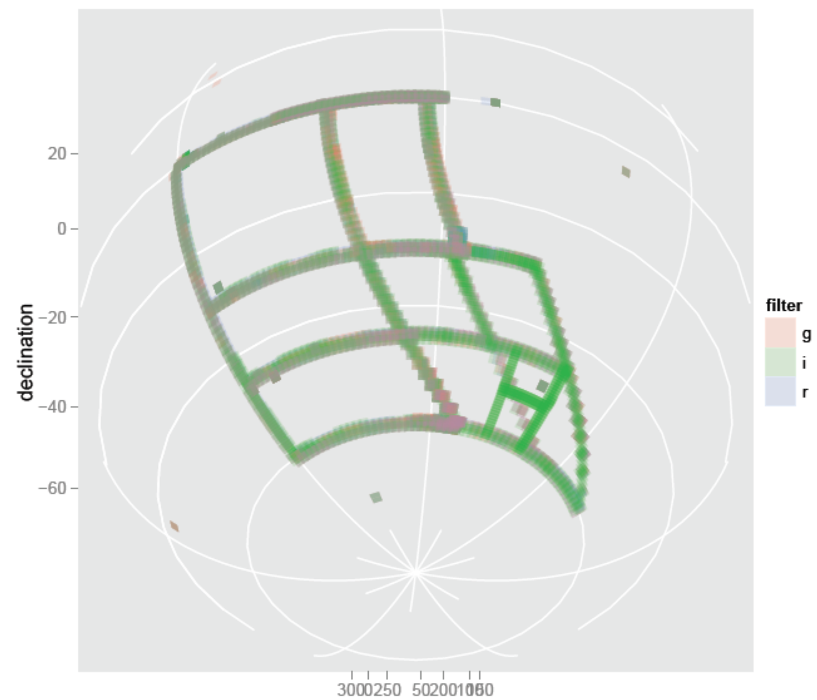
= DES footprint = PreCam "Sparse Grid"

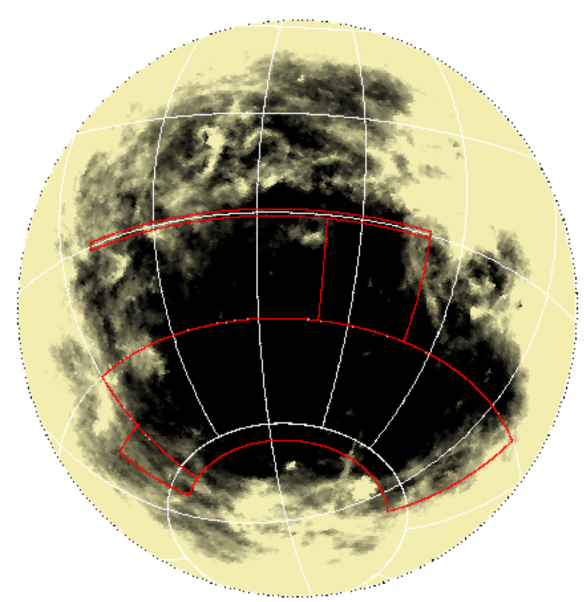
Band	PreCam Exposure Time [seconds]	PreCam saturation limit	DES saturation limit (100s exposure)	PreCam mag limit (S/N=50)	PreCam detection limit (S/N=5)	# Stars per sq deg, DES sat to PreCam S/N=50
(1)	(2)	(3)	(4)	(5)	(6)	(7)
g	36	12.8	16.3	17.8	20.9	186
r	51	13.2	16.3	17.8	20.7	265
i	65	13.4	16.2	17.7	20.5	344
z	162	14.1	16.0	17.5	20.1	317
y	73	11.6	14.3	15.8	18.5	150

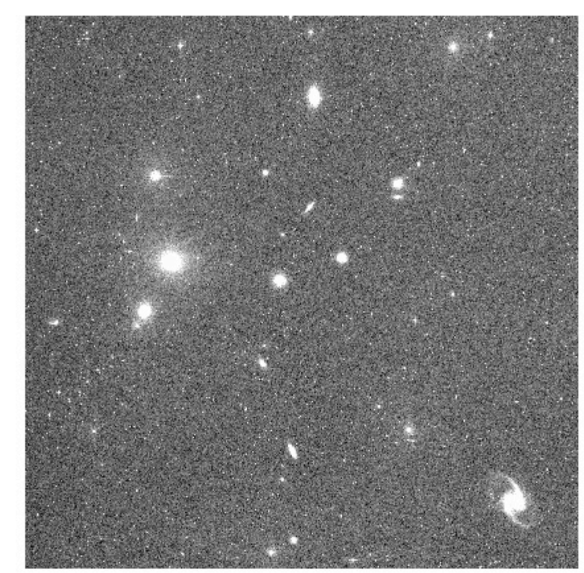
PreCam Preliminary Results

PreCam acquired ~25000 images in a "sparse grid" observing pattern over the DES footprint, including 25 passes over SDSS Stripe 82 in grizY filters, and multiple passes in gri filters over the remainder of the footprint.

Analysis of calibration and science data has begun at at Brazil, Fermilab, and Argonne. Goal is to define catalogs for astrometry and photometry, as well as to understand and mitigate any hardware, software, or other problems which could impact DES...

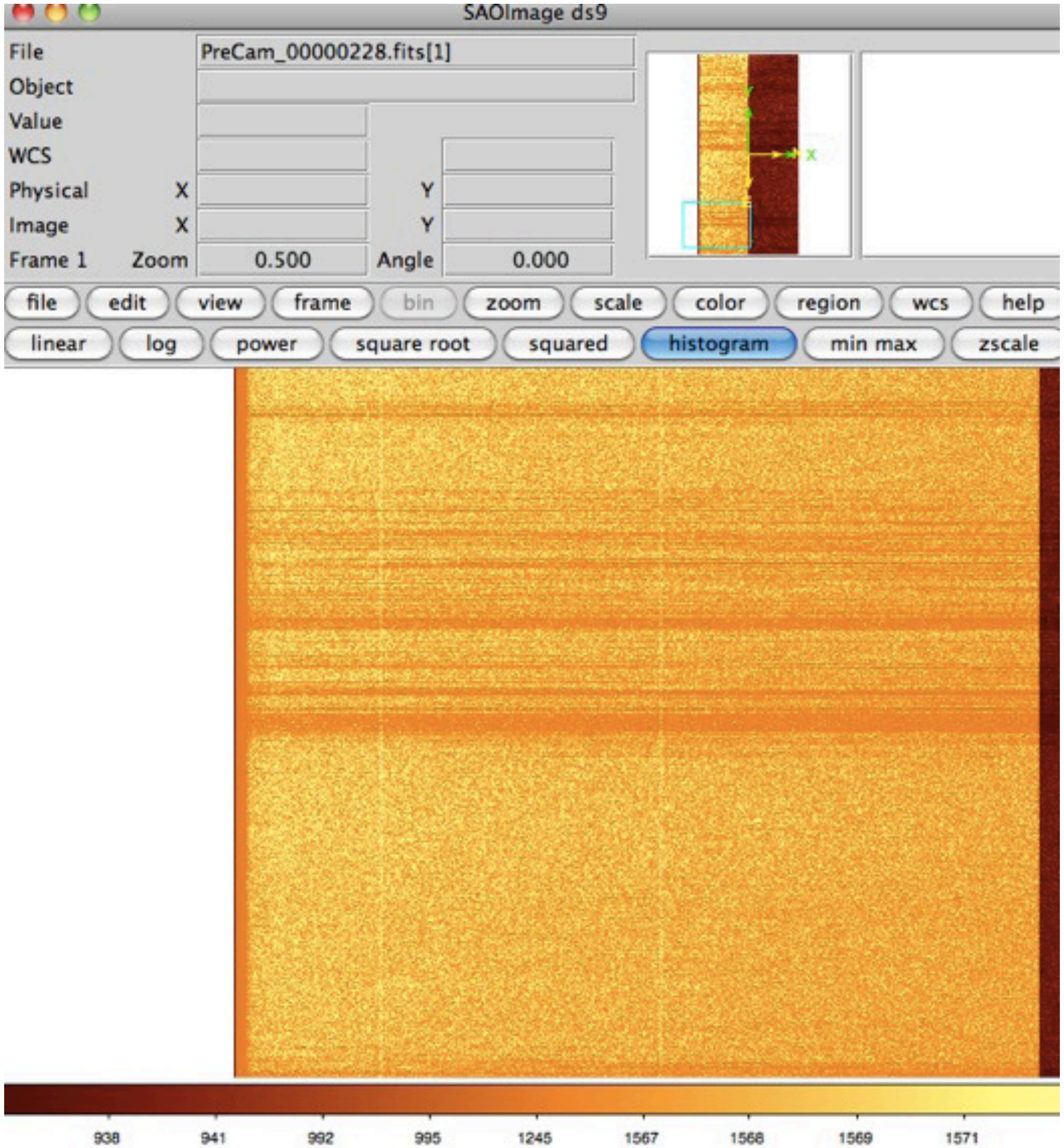


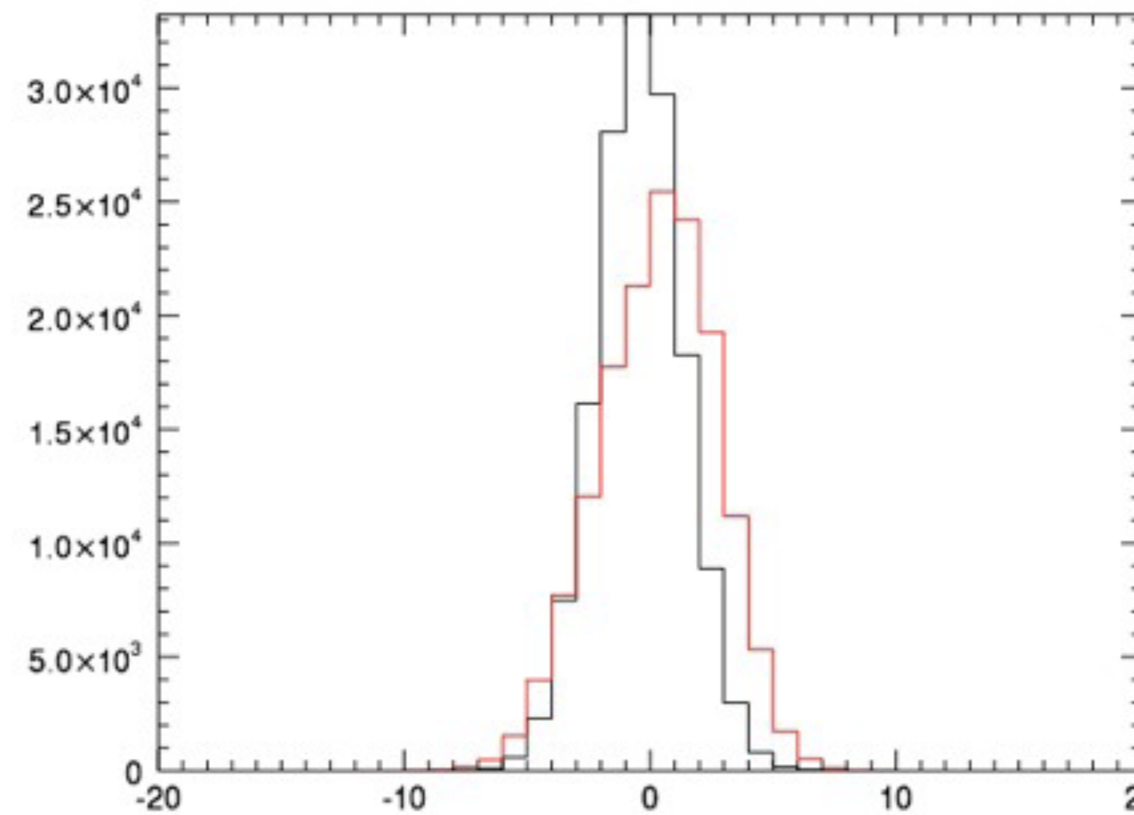




Previous Digital Sky Survey

Banding in PreCam Images





clean images (mean,stdev): 1568.59 1.24758

banded images (mean,stdev): 1567.49 1.72131

This image is from a bias exposure with telescope tracking on and dome on; slight ‘banding’ can be noticed in parts of the image.
In this image, at least, the effect is small and results in only slightly increased noise (this is in ADU).
Even slight movement of the connectors to the readout electronics (MONSOON) crate can cause significant banding. Gravitational loading is thought to have caused (microscopic?) damage to the connectors.

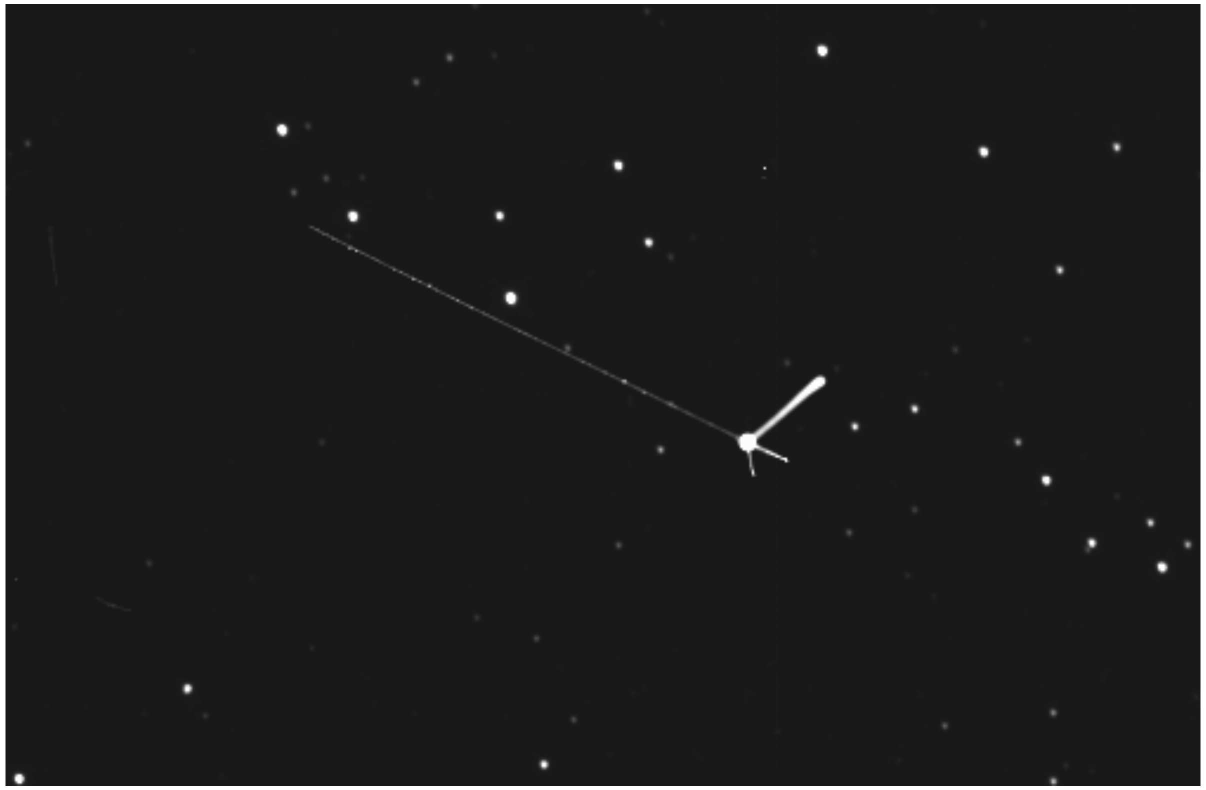
Degradation of PreCam CCDs

In one year (2/2010 to 2/2011) PreCam CCD full-well degraded from 180k ADU to 130k ADU.

Applied substrate voltage + increased input intensity (prolonged exposure to ambient sunlight, or even a few hundred W of interior room lighting within a few meters of the CCDs) can cause permanent damage.

DES will incorporate light-meters into a feedback loop that will power off substrate voltage if unsafe levels of light are detected.

Cosmic Rays in DECam CCDs

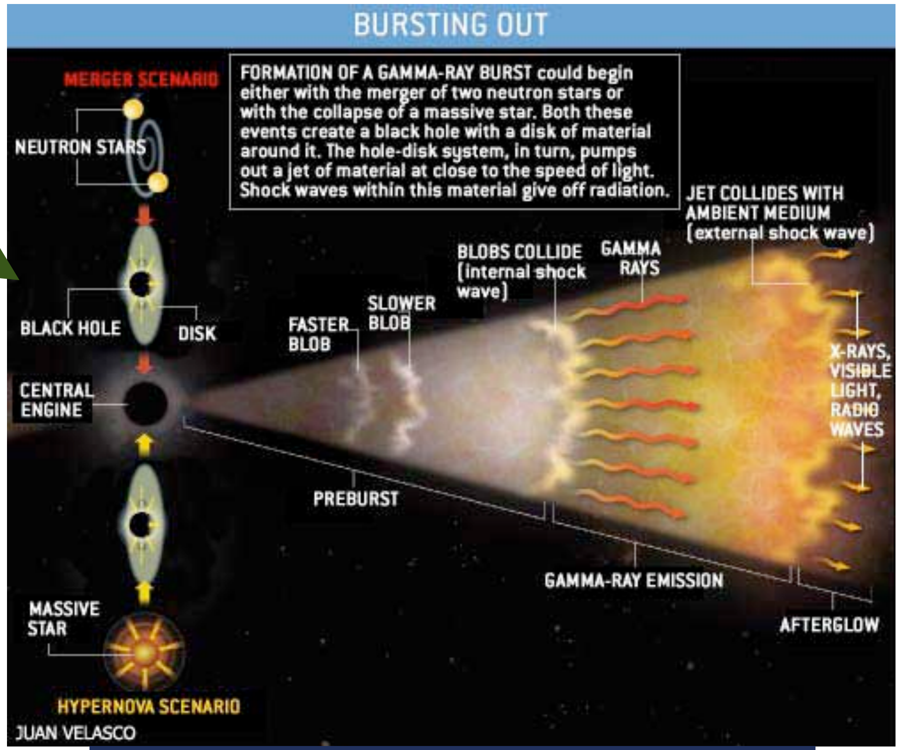


"The event is [most likely] a high energy neutron (100 MeV-1 GeV) colliding with a Si. The blob in the center is a nearly stationary fluorine and the four tracks in the detector plane are three protons and an alpha.
The long track on the left is not minimum ionizing as there are two other muon tracks in the image that are fainter.
Yes, it is highly unlikely that all these particles stayed in the detector plane and that the one proton on the left stayed in the detector plane for ~4mm but it seems to have happened here.
It is also possible that the long track is an incoming proton that caused the interaction but protons are not as common as neutrons at these altitudes."

Transient Science with DES

- **Stamp Collecting (esp. Jet Properties)**:

  Add to GRB statistics via multiwavelength/ multimessenger campaigns



- **Serendipity**:

  Interesting/unique GRBs--e.g. brightest (GRB080319B @10^{54} erg iso) or closest (GRB030329 at z=0.16) or most distant (GRB090423 at z=8.2)

- **Host Galaxies**:

  Metallicity--c.f. Modjaz et al. (2008)

  Morphology--e.g. LGRBs in star-forming galaxies, SGRBs in (outskirts of) ellipticals

  Absorption (ISM/IGM)

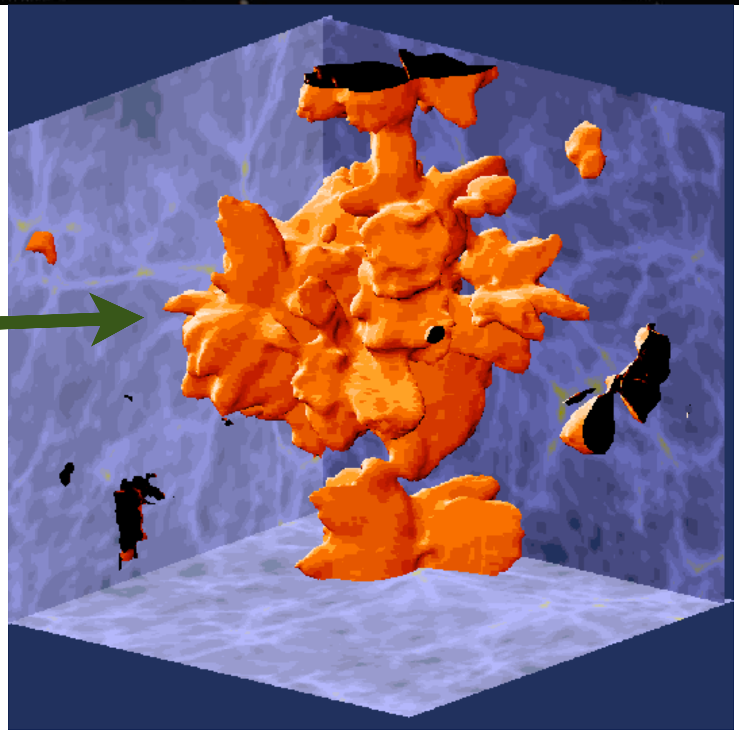
  Redshift (photo-z, dropout of successive bands)

- **From Star Formation to Cosmology**:

  Primordial (Pop. III) star formation, reionization,

  Standard(izable?) candles--Amati and Ghirlanda Relations (Amati et al. 2002, Ghirlanda et al. 2004), Liang-Zhang Relation (Liang et al. 2008).

  However, see Friedman & Bloom (2005)...



- **Pre-discovery images to GCN in "real"-time**

Quantitative Estimates of DES Contributions

Assuming:

~300 GRBs detected per year (by Swift, Fermi, etc.)

DES Footprint covers ~1/8 of sky

Afterglows can be brighter than 24th magnitude for as long as a month

Then:

There are approximately one GRB and 3 afterglows per week in DES footprint.

- Some we will observe “for free”, during the course of the standard survey
- Some will be in-footprint, but out-of-sequence (ObsTac ToO’s)
- Using 1% of survey time (2.5 hrs/month), we can obtain tens of minutes of data for the 5% “most interesting” GRBs/Hosts, regardless of sky position...

  This can be single, deep observations in multiple filters or shorter, multi-epoch observations spread out over the month, or anywhere inbetween.
- Any of these can incorporate DES time and/or Community Use time in conjunction with External Collaborators.

- Possibility of observational follow-up, independent of DECam?

GCN: “Real-Time” Data for the GRB Community

For such transients, obviously time is of the essence...

Gamma-Ray Burst Coordinates Network provides near-real-time information to multi-wavelength/multi-messenger observers around the globe. From detection to dissemination can be <1 minute.

Notices are moving to standardized (machine-parseable) format...

After one year, DES will have “pre-discovery” images of 1/8 of all GRBs (30-40/year). DES can “ingest” GCN Discovery Notices, parse RA/DEC (+errors), and immediately respond with multi-band images of the relevant region, thus rapidly providing finding charts, (potential) host galaxy information, and more to all observers in the GRB community.

Follow-up DES observations of tiles with GRBs, Afterglows, or Host Galaxies can provide more precise colors, morphology, SFR, etc., and can contribute significantly to ongoing multi-wavelength campaigns.

DES data will be proprietary for the first year, but the GCN Interface Tool will be extremely useful to the entire community long after that period.

Next step: Collaborate with IceCube to modify their OT Alert System for implementation in DES.

Current DECam Status

DECam is currently (during the week of Feb. 14–18) engaged in a “mock observing run” on the Telescope Simulator at Fermilab. All camera hardware (with the exception of the optics) has been assembled at Fermilab, and all control software is in functional (if prototype) form.

The Future of DECam and DES

DECam components at Fermilab will be disassembled in March 2011

Shipping to follow; some components (e.g. f/8 handling system) at Cerro Tololo

Installation of DECam components on Blanco from January 2011 to October 2011 (Shutdown of telescope starting in August 2011)

Commissioning of DECam November 2011 to March 2012

Preliminary observations (prior to Community Use) in March/April 2012

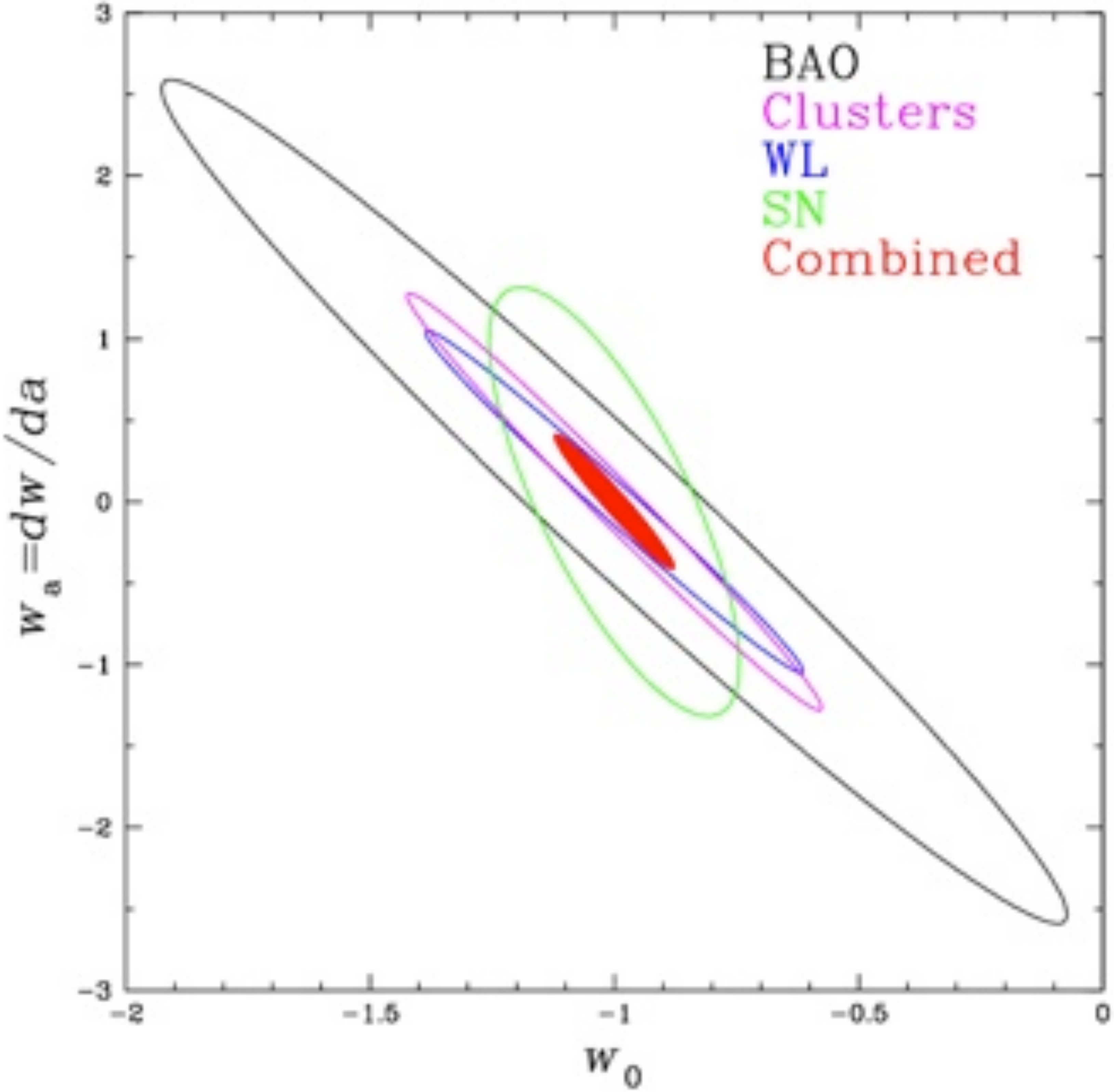
Survey officially begins in September 2012 (data proprietary for one year)

First year data release in late 2013/early 2014

3-year and 5-year (full) data releases follow

Expect a wealth of non-DE science for both DES and Community Users!

Final (expected) constraints on DE EoS of <10% for w_0 and of order 20% for w_a


BAO
Clusters
WL
SN
Combined
$w_a = dw/da$
w_0
3
2
1
0
−1
−2
−3
−2
−1.5
−1
−0.5
0